the moral and the military humiliation of France. Said Pasteur:

> France has done nothing to keep up, to propagate and to develop the progress of science in our country. * * * She has lived on her past, thinking herself great by the scientific discoveries to which she owed her material prosperity, but not perceiving that she was imprudently allowing the sources of those discoveries to become dry. * * * While Germany was multiplying her universities, establishing between them the most salutary emulation, bestowing honors and consideration on the masters and doctors, creating vast laboratories amply supplied with the most perfect instruments, France enervated by evolutions, ever seeking vainly for the best form of government, was giving but careless attention to her establishments for higher education.

Each year shows more clearly how true this view is, and how fully it applies to the triumphs both of peace and of war. Japan has even more profoundly impressed the world by her knowledge of scientific fact and by her rigid application of that knowledge than by the valor and military skill of her soldiers and sailors. No people are more in need than our own of learning the all-important lesson that the modern Germans and the modern Japanese have to teach. Respect for the man who knows and loyalty to demonstrated truth are characteristics of civilization that is founded on rock. Our American happy-go-lucky, wasteful way of approaching a serious problem, our naïve egotism and our exaltation of the man who does things, no matter how, must sooner or later give way to more patient study, to more respect for the experience and wisdom of other countries than our own, and to more regard for correctness and sound principle, than for a superficial costly 'efficiency,' if we are to hold the place in the world's esteem for which we are rightfully ambitious.

This institution is to be welcomed, then, not alone for what it will do for medicine, and not alone for what it will do indirectly for the relief of suffering human beings. It is to be welcomed still more for the lessons it will teach to our public opinion; for the guidance it will offer toward a juster appreciation of the relations between theory and practise, between observation and reasoning; and for the assurance it affords that generous support is to be had in this dear country of ours from men of affairs for research of the highest and most severe type.

Of the subjects with which the institute is to deal, when we reflect upon their variety, their far-reaching importance and their manifold relationships, can we say less than Faraday once wrote to Tyndall:

> Our subjects are so glorious that to work at them rejoices and encourages the feeblest, delights and enchants the strongest.

NICHOLAS MURRAY BUTLER.

THE educated public needs to obtain a clearer idea than it now has of scientific research, of its objects and results, and of the character and capacity of the men who devote themselves to it. The educated classes have a tolerably accurate conception of research in such subjects as history including antiquities, economics, philology, law and government; for research in these subjects relates chiefly to the past, remote or near. The public has also been long interested in the inventor's resourceful and persevering habit of mind—the inventor who is trying to make some new application of acquired knowledge, or to discover a new fact or principle which can be put to commercial use. But scientific research is somewhat different from these other kinds of research. It has deep roots in the past; but its object is never to demonstrate merely what has been done or said, or to obtain a monopolistic profit. Invariably its object is to extend the boundaries of knowledge, and to win new power over nature. It is not chiefly concerned to enlarge records of the past, or to make them

more accurate, but rather to use all the powers the past has conferred on the human spirit to win new power. The past gives the scientific investigator his lever and the present his fulcrum; but his work is to take effect on the future, and is to give him or his successors a stronger lever and a better placed fulcrum. As a rule, scientific research is carried on with no public observation, and as silently as nature elaborates and throws out the mantling verdure of spring; but on an exceptional occasion like this, and in a country which has already reaped great benefits from the endowment of institutions of education and charity by public-spirited persons, it is fitting that the beneficent work of the scientific investigator should be accurately described, and commended to the favor of an enlightened public opinion.

Let us first consider what mental habits and powers the scientific investigator needs to have acquired and to keep in exercise, or in other words what sort of a mind the investigator ought to have. In the first place, he needs the faculty and the habit of determining and grasping facts, and then verifying and digesting them. He must next be capable of conceiving hypotheses which will connect his facts, or explanations that will group them or arrange them in a series. These hypotheses or explanations will come to him as results of reflection or of imaginative scheming; in the common phrase, ideas will occur to him. A preconceived idea may be a great power in experimental researches; but the inquirer must have the habit of pursuing to verification or disproof all such ideas. He must test them by new experiments contrived for that purpose. He must exhaust all the adverse hypotheses which come to his mind. He must always keep in the road that leads to truth, although he does not know just where the truth lies. If through the play of his imagination he gets off the right road, his rigorous experimentation must bring him back to the safe path of the inductive method. He must possess patience and reserve, but also enthusiasm and a capacity for eager speculation. Science has often profited by a suggestive theory, which was far from being true. Indeed, the history of scientific progress is full of these profitable theories, which have been abandoned one after the other; and in all probability the series of such theories will prove to be infinite. Sometimes theories long forgotten are taken up again after the defeat of the later theories which caused the forgetting of the earlier. However it may be in theology, it is quite certain that in science there is as yet no such thing as final truth. Accordingly, investigators in any science need an unusual perspicacity or clear-sightedness in regard to its theories; they need, each in his own field, a full knowledge of the work already done, and a clear perception of the bearings of the most recent discoveries. This perspicacity is in some measure a natural gift; but it is also a faculty capable of a high degree of training. It sees clearly the approximate truth already discovered, and goes forward to obtain a closer approximation.

The general features of scientific research are similar in all fields, although each kind has its peculiar difficulties. The field of the individual inquirer need not necessarily be wide; although the progress of many sciences is often contributory to the progress of one, and that investigator has a great advantage who is capable of seeing clearly the bearings of new discoveries in kindred sciences on the particular inquiry he has in hand. It is all-important, however, in all fields, that the investigator should be capable of seizing on the essential parts of the inquiry—that is, on

its causative elements, rather than on those parts which relate to identification, classification and nomenclature. The pioneers of science, like the pioneers in exploration and colonization, must find their way through pathless regions. It is only later generations that build smooth roads and railways for the transportation of inattentive multitudes where the pioneer trod alone and watchful. The investigator must be watchful over minor details and for apparently insignificant differences and similitudes. He must know how to find his clues in trifling circumstances and illusive changes of condition. In these days of germs and spores, when micro-organisms have been proved to be infinitely important in the economy of nature, the investigator, and especially the biologist, will probably have a peculiar conception of the great and the small, or the gross and the minute. The infinitely little may often seem to him of highest importance, his scale of values having no connection with spacial magnitude or gravity. On the other hand, the investigator must be keen to discern relationships among facts—first among facts easily classed as kindred, but then among facts which to the common mind are unconnected or disconnected. The intellectual tastes of the true investigator will usually include a liking for the elucidation of mysteries, and a liking for new and adventurous problems. These tastes are manifested by men whose walks of life and objects of interest are very different; but they are not common tastes, any more than the faculties needed in such inquiries are common. The scientific investigator wins pleasure or satisfaction where most men and women would find only vexation and futile effort. He finds fascinating what most men and women would find repellent.

After a new discovery has been made, another and quite different task awaits the successful investigator. He desires and needs to procure the acceptance of his discovery by the learned world, and in some cases by the commercial world. This is a process different from the process of discovery, and yet kindred. It involves demonstrations; but these demonstrations require a somewhat different sort of imagining and contriving from that which led to the discovery. The discovery was made in private; the demonstrations must be public. The discovery needed solitary reflection; to procure the acceptance of the discovery needs a power of public exposition, accompanied by debate and even controversy. The discovery required indomitable patience and energy in pursuing and verifying in rapid succession the conceptions or fancies of genius; the demonstration requires skill in discussion, courage in accepting public tests, and in taking responsibility for risking the property or lives of others.

The history of scientific research amply illustrates the stimulating value of controversy, and the contribution which free discussion makes to real progress. Freedom of thought and speech promotes progress towards truth in science just as effectively as it does the gradual attainment of truth and justice in government, industries and social structure. Time frequently shows that both sides were measurably right in honest scientific controversies, although one side win a temporary or even an ultimate victory.

The conditions under which research is necessarily performed deprive the investigators of the stimulus which numbers of students give to popular teachers. The laboratories of research contain but few students; and they are for the most part silent and absorbed. Nevertheless, the younger investigators have two great satisfactions in their work: they follow leaders

with hearty enthusiasm and loyalty, and the generous ones among them also maintain a stimulating comradeship with contemporaries in the same fields. Their number is very small in all the contemporaneous fields of inquiry put together; but it is on this small number that the real progress of any nation in the arts and sciences, and, therefore, in civilization and happiness, ultimately depends. Their Herculean labors are self-imposed, and they must set their own standards of excellence; for society can not supply men capable of supervising, regulating or stimulating them. The ordinary grades of public instruction can be supervised and disciplined; but the scientific investigator must be a law unto himself. The utmost that governments or universities can do for him is to provide suitable facilities and conditions for his work, and to watch for results.

Among the numerous varieties of scientific research such as chemical, physical, physiographical, astronomical and biological, medical research occupies a peculiar place. While it avails itself to the utmost of all the exact weighings and measurings of the other natural sciences, it is forced to deal with innumerable materials and conditions which are complicated and made obscure by vital forces. It has to deal with objects which are alive and with processes of organic growth or change. Its evidence can not always be exact; its experiments must often be complicated and obscured by vital reactions; and its results of highest value are often incapable of complete demonstration in the mathematical, physical or chemical sense; because dense shades of ignorance darken the environs of the practical result. Thus, preventive measures against a familiar and definite disease may succeed, while the promoting cause of the disease remains unknown, and the method of its transmission from one victim to another is but imperfectly understood. Vaccination succeeded when the cause or promoting condition of smallpox was unknown. The microbe of rabies is unknown, and yet protective inoculation against rabies has been invented and successfully applied. The mere mention of some of the contributory inventions and discoveries of the past fifty years, such as the principles of fermentation, artificial culture solutions, gelatine plate cultures, selective cultivation, the variety of sterilization conditions for different organic substances, staining technique, immunity through the use of a toxic organism that can be cultivated, increasing or diminishing at pleasure the virulence of a toxic organism, and testing toxins and vaccines on living animals, will readily satisfy even a sceptical mind that medical research has great difficulties of its own to encounter in addition to the usual difficulty of scientific inquiry in general. Biological research is, therefore, more arduous than physical, chemical or other inorganic research, because vital processes are difficult to observe accurately, and all the conditions of experimentation are harder to control. The medical investigator must often fish in troubled waters; and sometimes he can not find again the promising fishing ground he has once visited, because unexpected fog prevents him from seeing the intersecting bearings of his desired ground.

Again, medical research habitually strives to arrive at something beyond abstract truth. It seeks to promote public and private safety and happiness, and the material welfare of society. Its devotees have in mind the discovery of means of remedying misery or warding off calamity; and they also know that whatever contributes to health and longevity in any community or nation contributes to its industrial prosperity; so that they are justified in hoping for results from their work which will promote human welfare. In short, medical

research is research in science which is both pure and applied. Some genuine scientists affect to despise applied science; and certainly it is not discreditable to men of science that they are apt to value discoveries which have no popular quality or commercial utility more highly than those which immediately attract the favor of the multitude by their industrial effects, or by their striking novelty combined with intelligibility; but all scientists recognize the fact that medical research is directly related to the largest material interests of the community, such as manufacturing, transportation, sanitation and the methods of providing light, heat and shelter, and of defending the community against frauds in foods, drinks and drugs. Many of its problems are economic as well as medical, and require in those who study them sound judgment in money matters as well as knowledge of natural law and skill in scientific methods of inquiry. Medical research, therefore, requires in its devotees a combination of theoretical power with practical power—a capacity for both abstract science and applied science. This combination is rare but by no means unattainable. Indeed, abstruse speculation is almost always attractive to masters of the experimental method. The investigator absolutely needs a powerful imagination; but this imagination must be checked by the most rigorous experimentation.

In spite of the fact that medical research involves the suffering and death of many of the lower animals used for purposes of study, the work of medical research is in reality the most humane work now done in the world; for its secondary objects are to prevent disease in men and animals, to defeat the foes of life, to prevent the industrial losses due to sickness and untimely death among men and domestic animals, and to lessen the anxieties, terrors and actual calamities which impair or crush out human happiness. The primary object in medical research, as indeed in all research, is the ascertaining of truth; but these secondary objects are ever before the mind of the investigator, and through them come his greatest satisfactions. These satisfactions ought to be shared by men who, like the founder of this institute, promote medical research by the exercise of their sound judgment and good will and by their money.

The achievements of medical research since Jenner have been marvelous. Seeing what has been done within a century to diminish the mental and bodily sufferings of mankind from smallpox, diphtheria, rabies, tuberculosis, malaria, yellow fever, puerperal fever and typhoid fever, and to give surgery safe access to every part of the body, we may reasonably believe that equal triumphs, and even greater, await it in the future. May we not hope that America will contribute her full share to the progress of scientific research, finding no obstacle, but rather means of furtherance, in her democratic institutions? May not we democrats find encouragement in the humble origin of Franklin, Faraday and Pasteur, and in the contributions democratic America has already made to anesthesia, surgery, the improvement of public water supplies and the control of Texas fever, malaria, puerperal fever and yellow fever? May we not reasonably expect our country to produce many men like Louis Pasteur's father, a private soldier of the first empire and a hard-working tanner? In the dedication of his best book the great son said to his father: "The efforts I have devoted to these investigations and their predecessors are the fruit of thy example and thy counsel." Let American parents take that sentence to heart! And let all Americans reflect on another utterance of this greatest of contributors to medical science, this ar-

dent patriot, this independent and indomitable worker, this genuine democrat—Pasteur: "The true democracy is that which permits each individual to put forth his maximum of effort."

CHARLES W. ELIOT.

SCIENTIFIC BOOKS.

A College Algebra. By HENRY BURCHARD FINE. Ginn & Company. 1905.

The present day is remarkable for its production of large numbers of mathematical text-books. In most cases the aim of the writers of these books seems to be to convince the student that the subject treated is devoid of any element of interest, that it possesses no logical sequence, and that memory of a large assortment of unconnected facts is the only requisite for a sound mathematical training. One meets with proofs of theorems divided into first, second, etc., steps—an obvious attempt to burden the memory at the expense of the reasoning faculty, and stress is laid on the fact that all problems are 'easy,' in fact on examination they appear scarcely worth the name of problems. There is not the slightest doubt that these harmful books are one of the causes of the decrease in mathematical students at our colleges and universities. The books are, unfortunately, given a trial somewhere, no matter how bad they may be, and one can conceive of no surer way of destroying the interest of the young student in the subject. For those who are merely general students they are equally defective. In the forefront of an author's mind should be a desire to develop the reasoning faculties. Let us have easy exercises by all means, but let us also have exercises which will make students think for themselves. Let us develop our subject along the easiest sequence, but let us develop it logically.

Professor Fine's 'College Algebra' is in refreshing contrast to such books as I have mentioned. He aims at giving an exposition at once logical and easy to understand. The result is a book that must make the subject interesting to the ordinary college student. The work is divided into two parts. The first consists of 78 pages devoted to the ideas at the base of the notion of number, a development of those ideas which are associated with the names of Cantor, Dedekind and others. This difficult subject has been handled by the author with conspicuous clearness, and every student of it should make himself familiar with these first 78 pages. It is questionable, however, whether, even with Professor Fine's exposition, it is possible to make this subject really understood by a student who is just beginning his college algebra course, and possibly the author in later editions may decide to present this section as a separate book, under a separate title.

The second part, some 500 pages, is concerned with algebra proper. It is 'meant to contain everything relating to algebra that a student is likely to need during his school and college course.' Even this wide ideal is given a wide interpretation, and the last chapter, Properties of Continuous Functions, is a fitting introduction to the calculus. The chapters on the solution of equations are of special interest. The author makes much use of graphs, the only way to make clear to the student what is implied by the solution of a set of equations. It would have been of advantage to give a brief account of the generalization of the use of graphs to the case of three variables, and thus to prepare the mind for the idea of a space of more than three dimensions. Particularly noteworthy in connection with graphs is the discussion of inequalities. The idea of a graph as dividing the plane into two regions, in one of which $f(x, y) > 0$ in the other < 0, should certainly be emphasized in ordinary algebra, before the introduction of analytic geometry, as algebraic questions, otherwise unintelligible to the learner, become almost intuitive. Observe, for instance, the illuminating example on page 341.

The general theory of the solution of equations is developed in very effective form; in particular the treatment of symmetric equations. The important idea is the taking of the various simple symmetric functions as new auxiliary variables and, after solving for these, finding the solutions of a set such as,